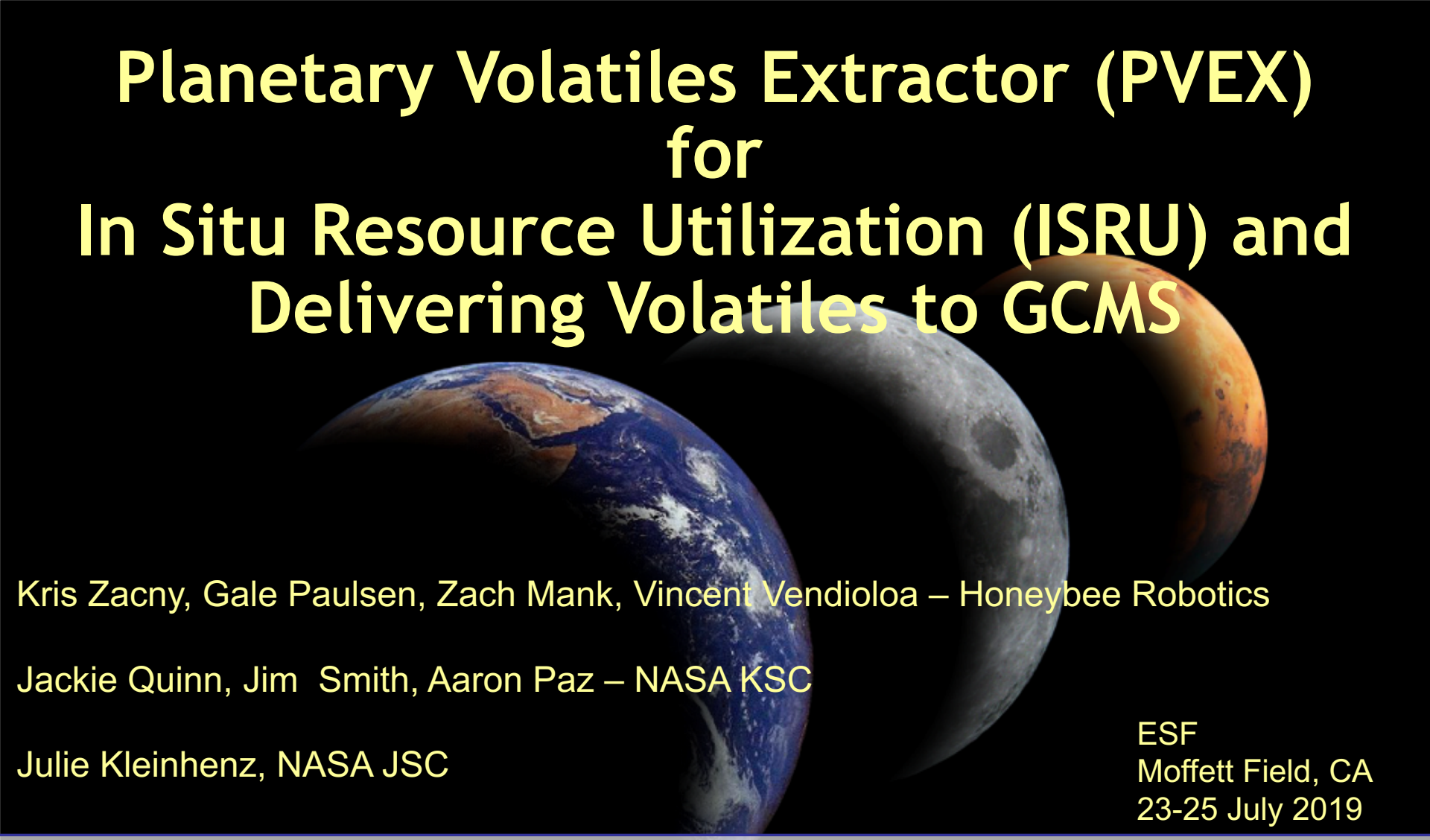
Planetary Volatiles Extractor (PVEX) for In Situ Resource Utilization (ISRU) and Delivering Volatiles to GCMS



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ESF
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Spacecraft Mechanisms Corporation

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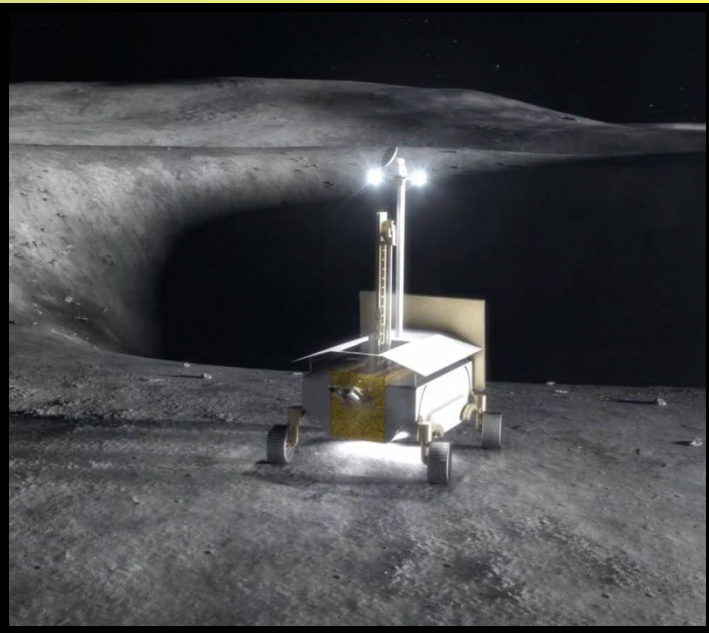
2 Steps in ISRU Process

1. **Prospecting:**
   - Determine “water **reserves**”
   - Reserves - raw material in-situ that is feasible to extract and processed with proposed mining approach.
   - Prospecting needs to answer:
     - How much
     - Where
     - How to extract etc.



2. **Production:**
   - Extraction and processing (if needed) of the raw material to form final product (in our case it’s water)

Two considerations…

It is not just water

Abundances of volatile compounds in the ejecta plume of LCROSS impact (Colaprete, 2010)

Compound	Molecules cm^{-2}	% Relative to $H_2O(g)$*
H_2O	5.1(1.4)E19	100.00%
H_2S	8.5(0.9)E18	16.75%
NH_3	3.1(1.5)E18	6.03%
SO_2	1.6(0.4)E18	3.19%
C_2H_4	1.6(1.7)E18	3.12%
CO_2	1.1(1.0)E18	2.17%
CH_3OH	7.8(42)E17	1.55%
CH_4	3.3(3.0)E17	0.65%
OH	1.7(0.4)E16	0.03%

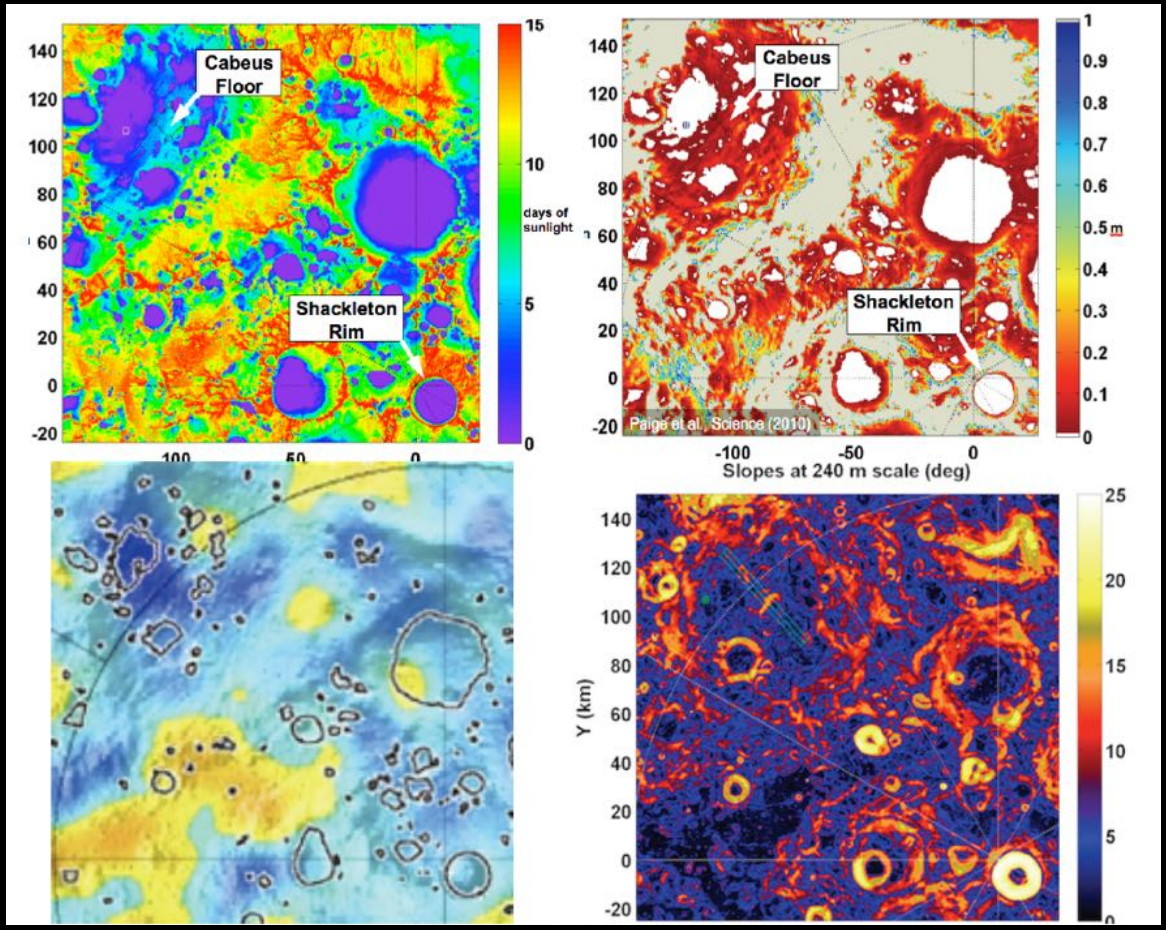
Recommendation:

- Need Mass Spectrometer to accurately determine all volatile species.

Where to go is not just about water

Heldmann, et al., 2012

Net days of sunlight



Depth to stable ice

LRO LEND neutron data

LOLA DTM slope data

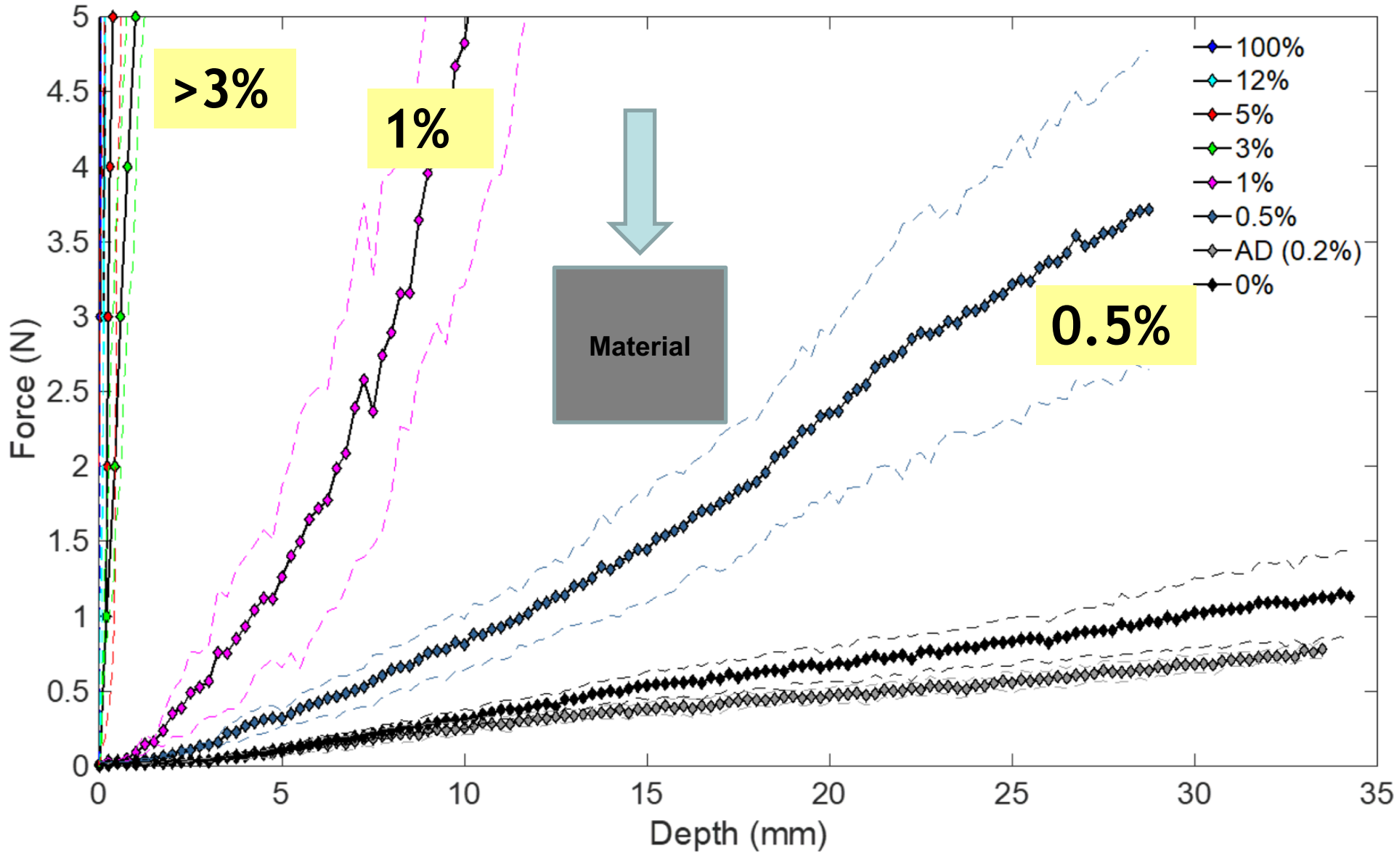
Recommendation:

- Need more than one data point (rover, several landers)
- Need Neutron Spectrometer and Near-IR Spectrometer
- Need excavation system to delivery samples

Concern #1: Excavation of Icy Soil

Strength of icy-soil: 0-100 wt%

Courtesy Jared Atkinson



Strength of icy-soil, >3 wt%

Atkinson and Zacny (2018)

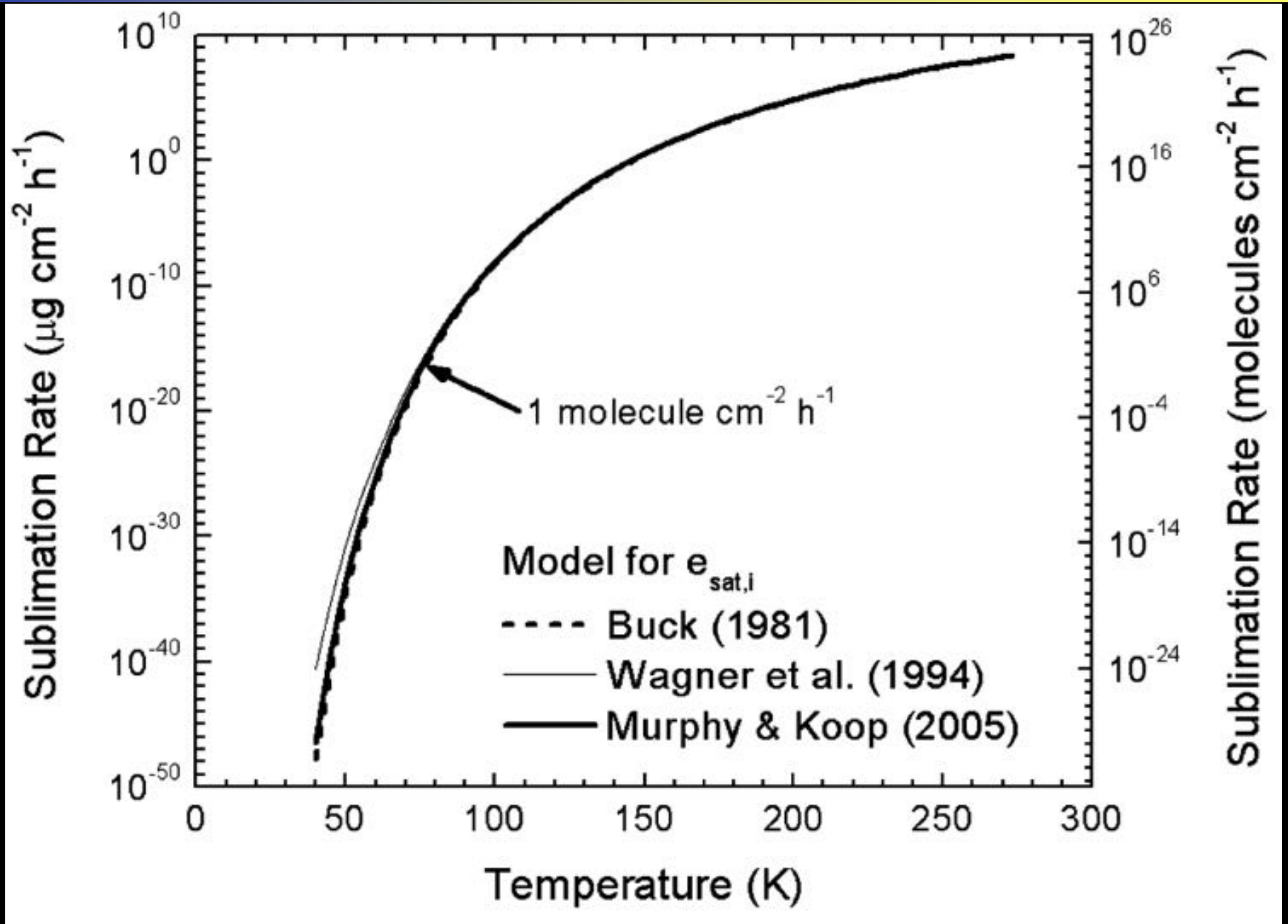
Recommendation:

- Need Percussive drill

Concern #2: Volatiles capture

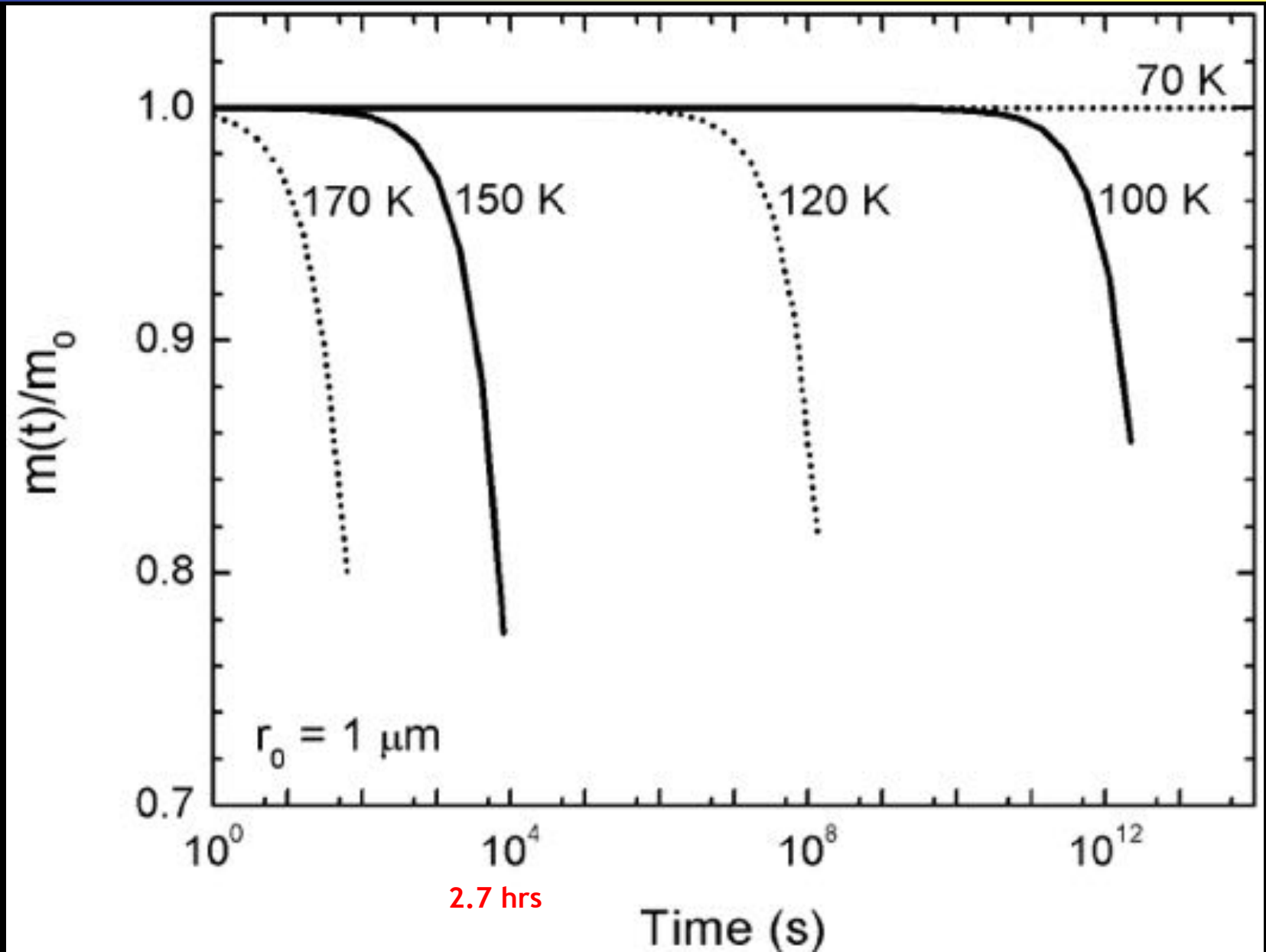
Sublimation rate

Andreas, 2006



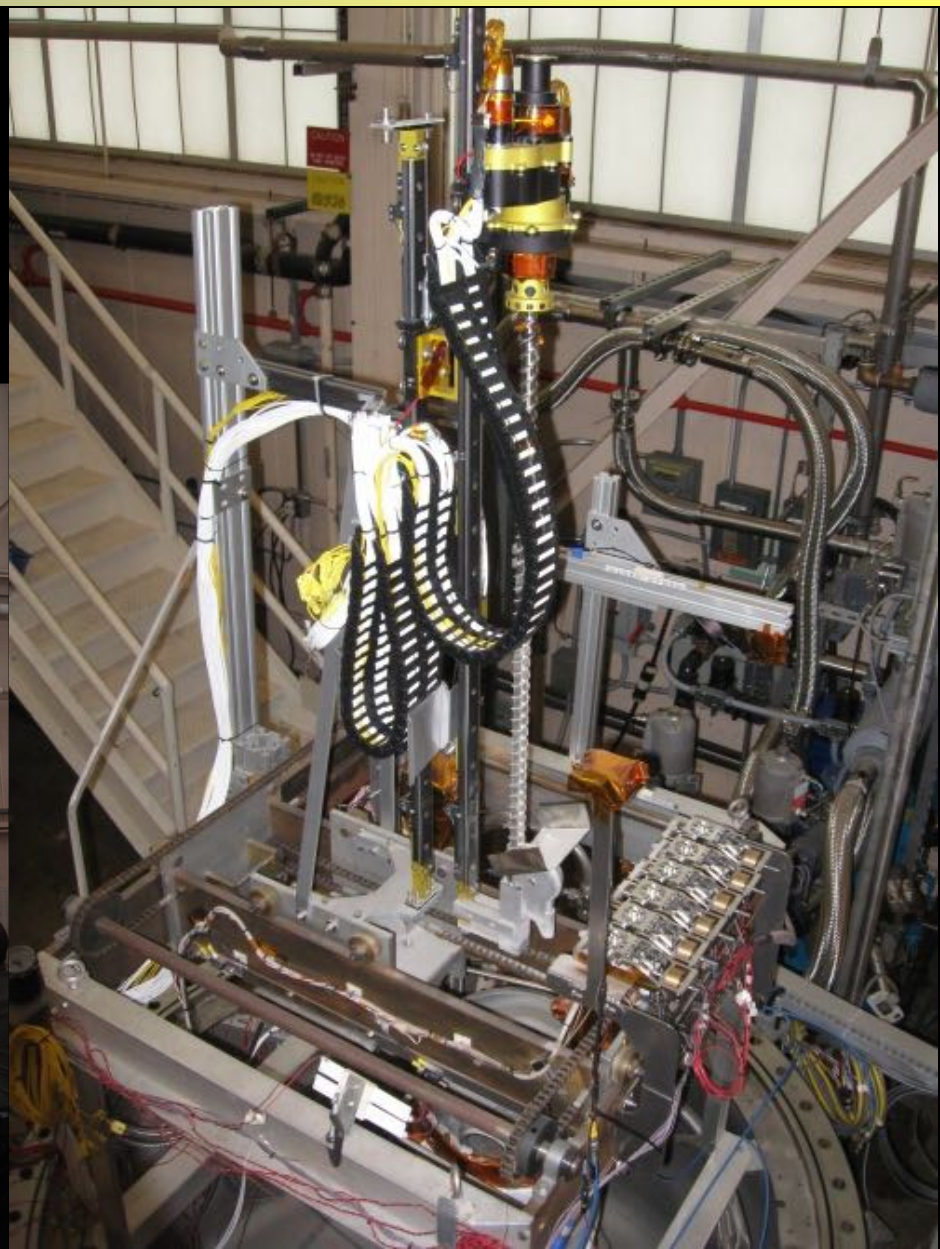
Sublimation rate for 1 micron ice particle

Andreas, 2006

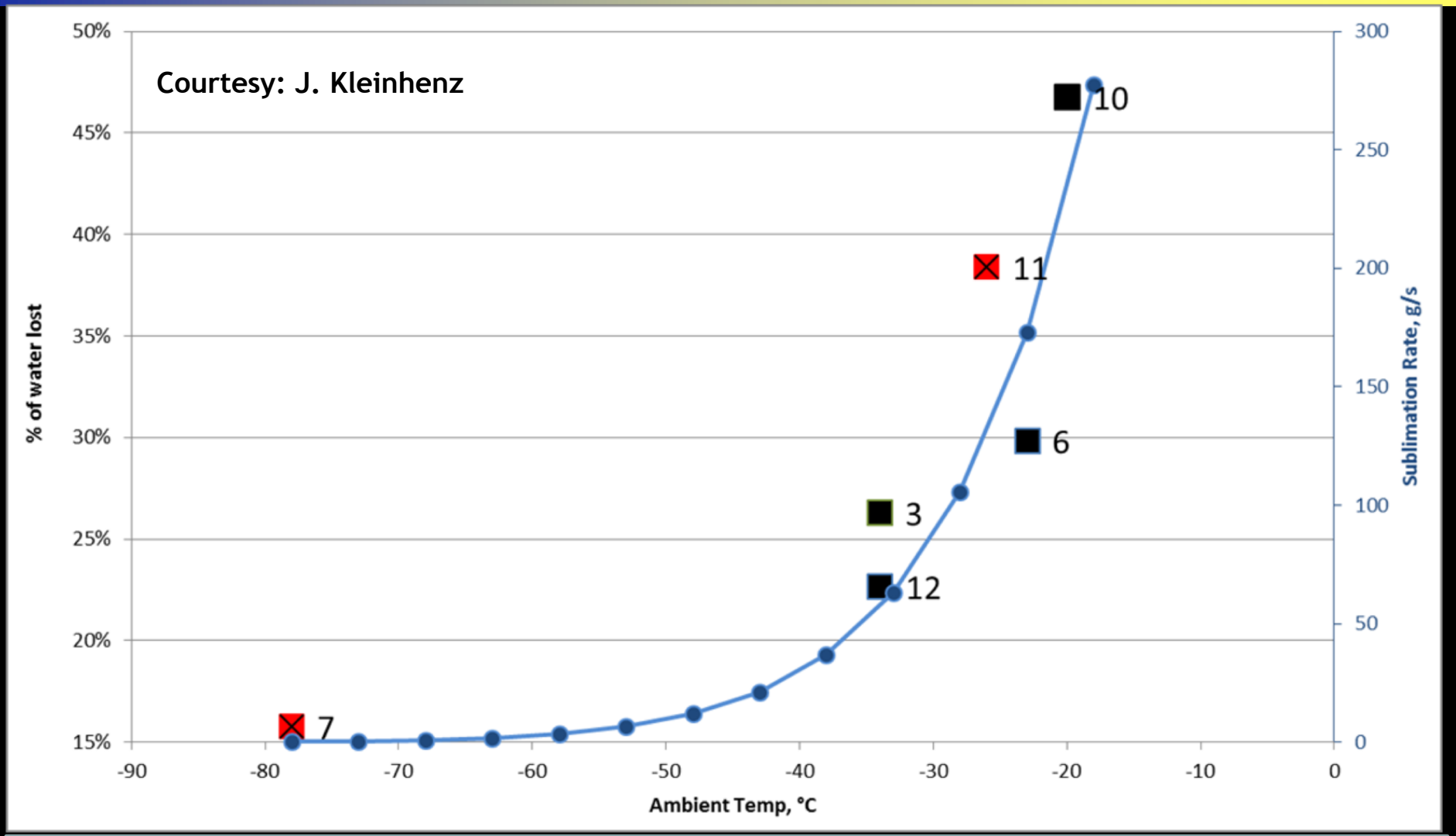


Tests at Lunar conditions (NASA GRC)

- **Soil:**
  - NU-LHT-3M with 5 water wt%
  - Vib. compacted to ~1.5 g/cc
  - Temp: -140 C to - 90 C
- **Chamber P:** ~10^-6 torr



Drill Test Results



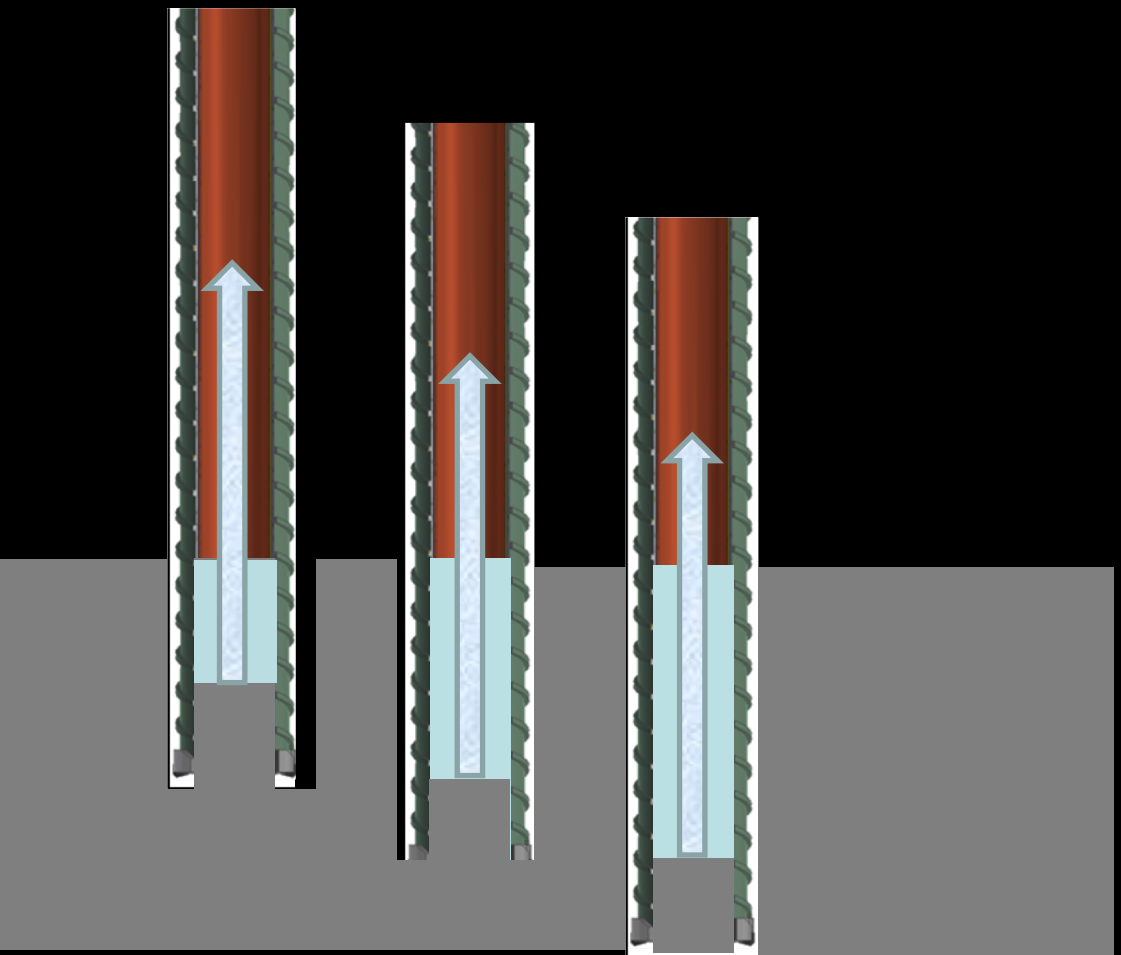
Recommendation:

- Need fast sampler delivery system or volatiles delivery system

Solution: PVEx

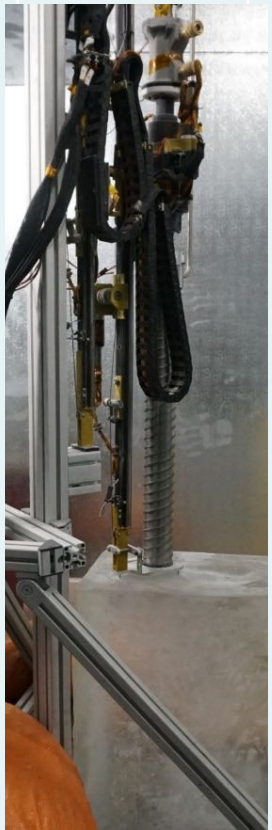
Planetary Volatiles Extractor (PVEx)

- Hammer drill – can cut strong material
- Coring auger – captures regolith
- Swivel/slipring – heats up and delivers volatiles

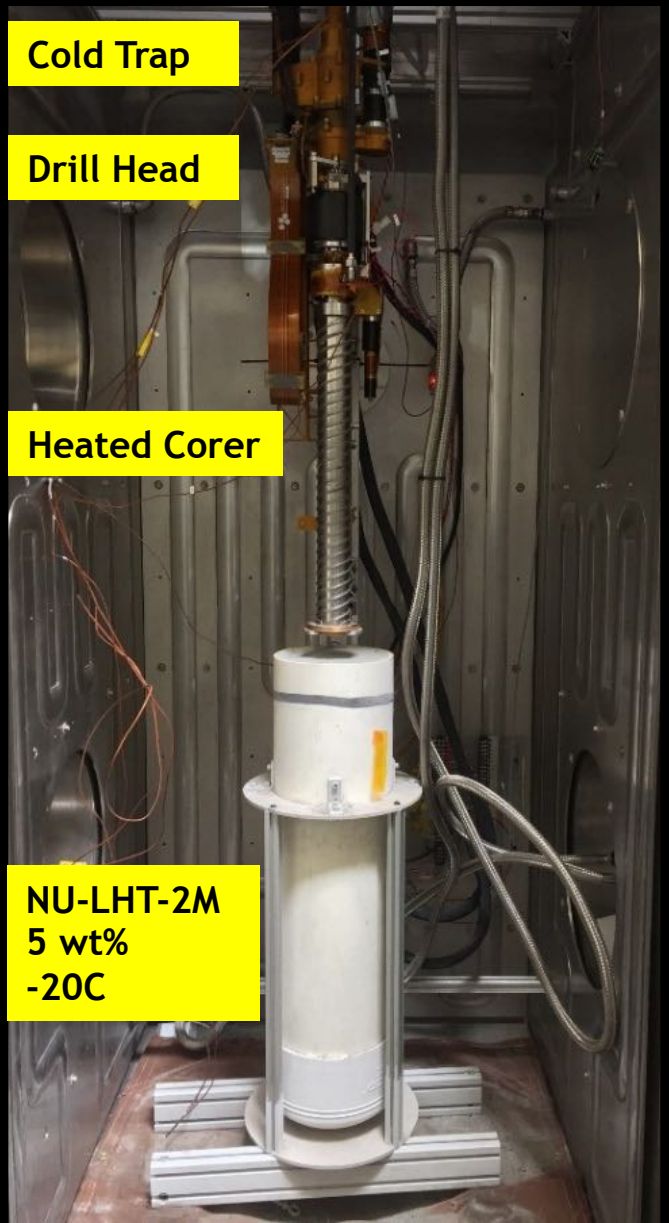


Drilling tests

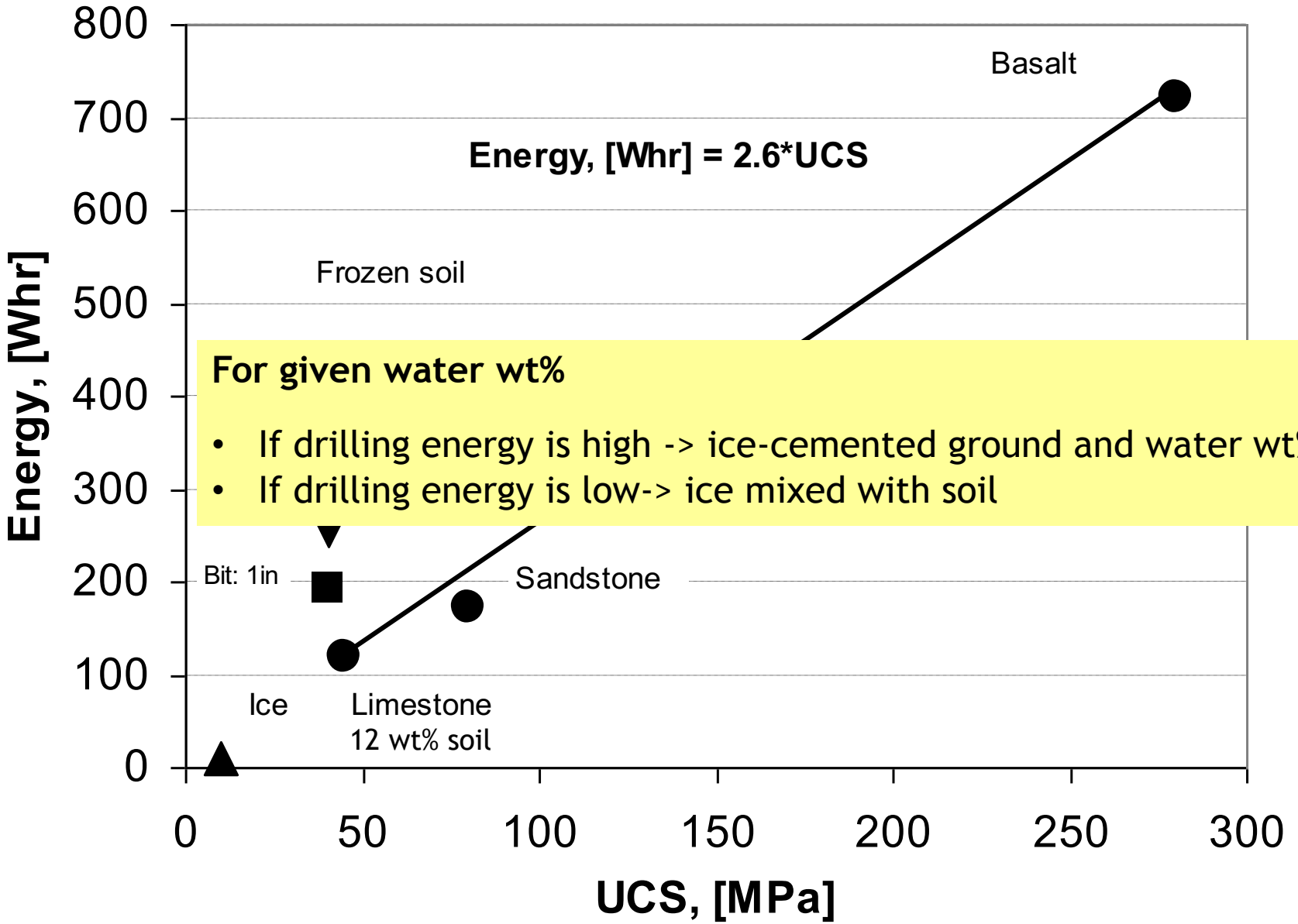
Material		Ice, -20C	Texas LS	Indiana LS		NU-LHT-2M, 5 wt%, -20C
Drill		LITA		TRIDENT		
Strength	**MPa**	5	23	45	45	5
Rate of Penetration	**cm/min**	5.7	5	1.8	1.9	5.8
Power (electrical)	**W**	246	242	142	141	180



Tests in 5 wt% NU-LHT-2M, -20C



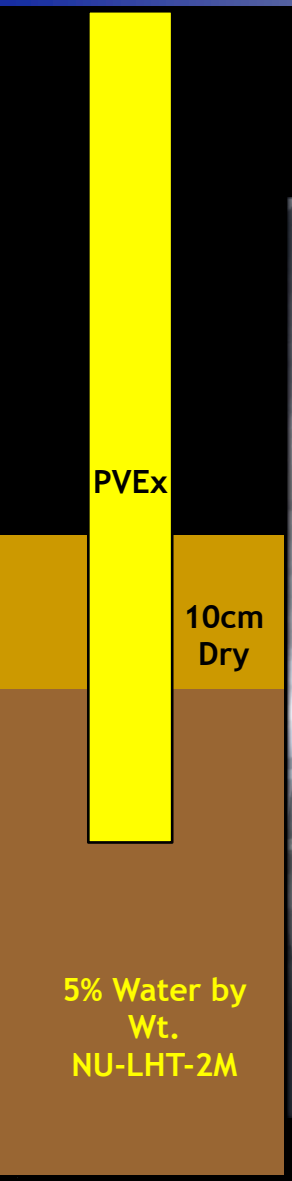
Drill data can provide wt% and form of water-soil

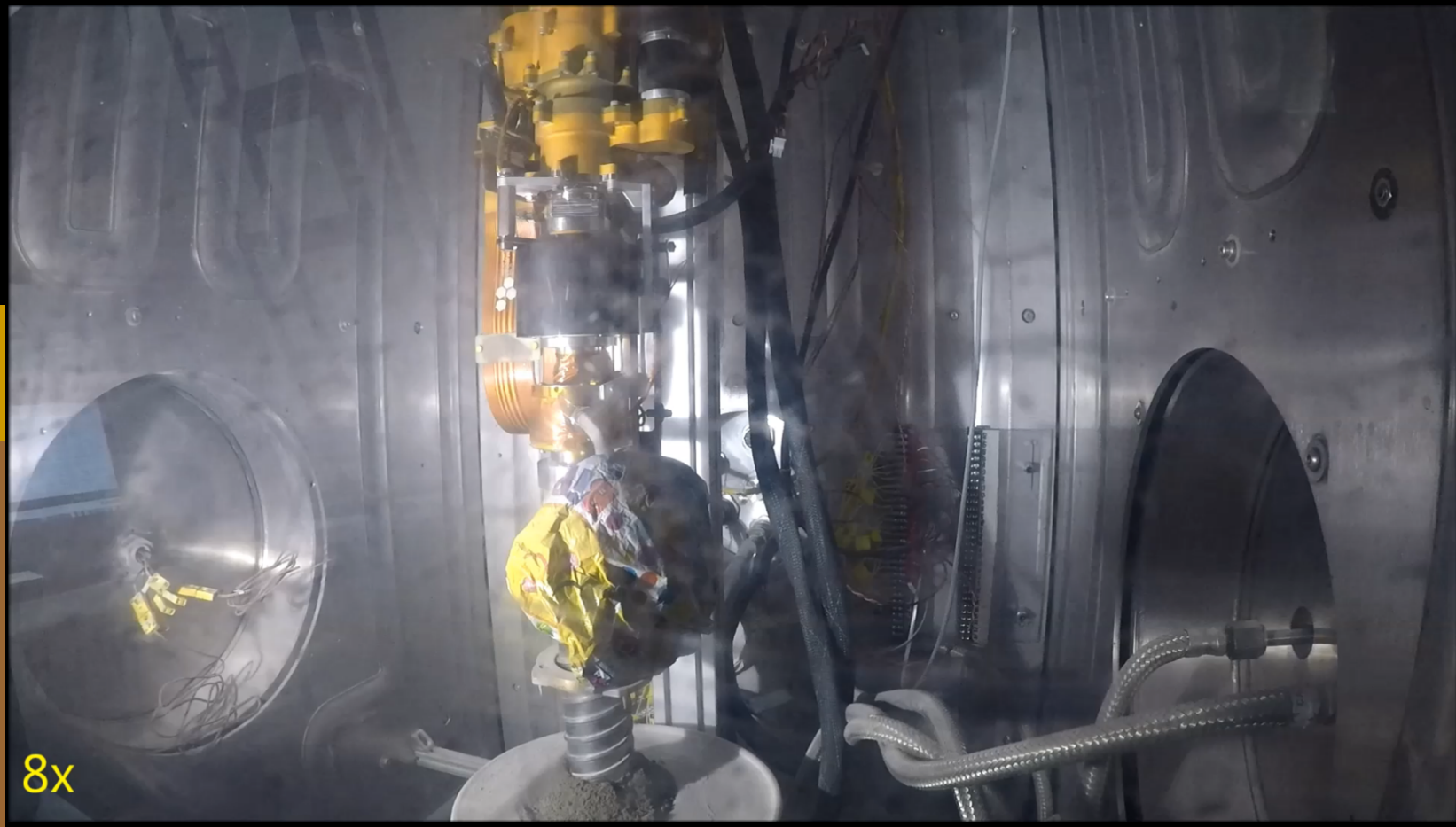


For given water wt%

- If drilling energy is high -> ice-cemented ground and water wt%
- If drilling energy is low-> ice mixed with soil

Volatile Delivery to MS (Prospecting)





PVEx on Prospecting Rover

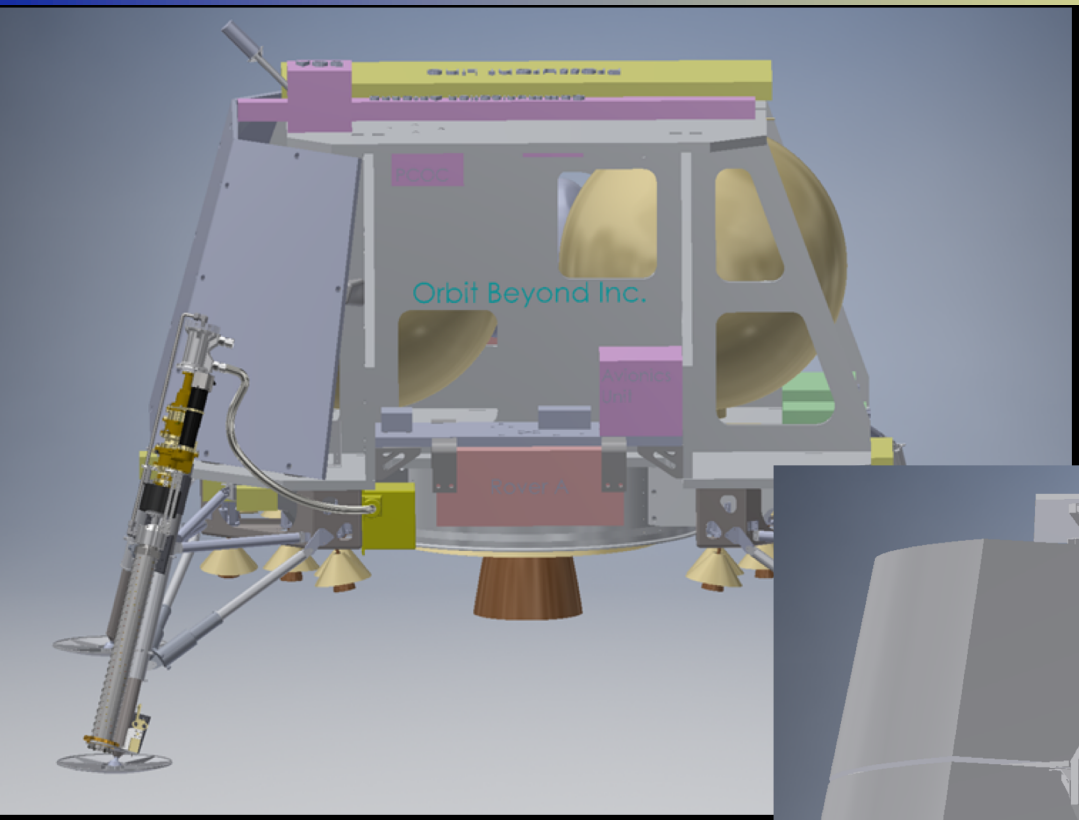
Planetary Volatiles Extractor (PVEx)

Neutron Spectrometer Subsystem (NSS)

Mass Spectrometer observing lunar operations (Msolo)

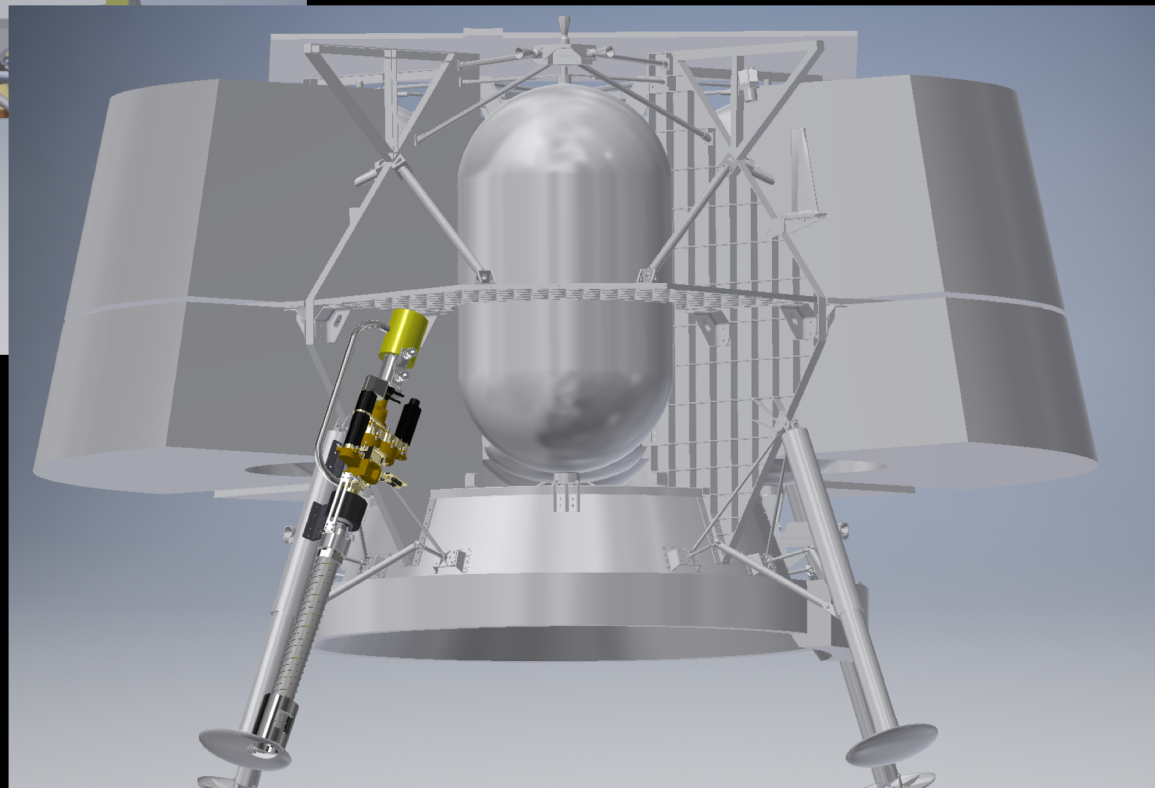
Near InfraRed Volatiles Spectrometer Subsystem (NIRVSS)

PVEx on CLPS Lander



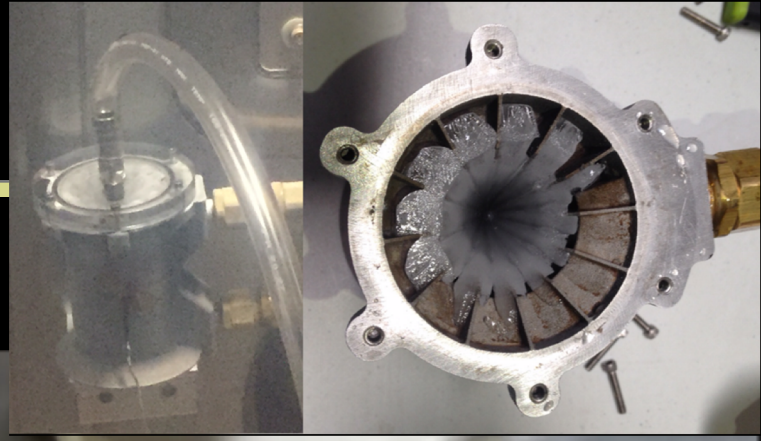
OrbitBeyond

Astrobotic



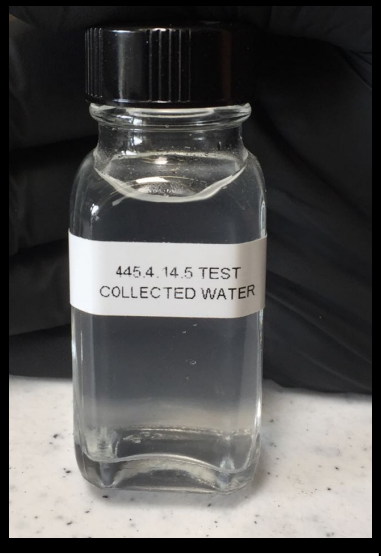
Volatile Collection (ISRU)

- deltaPressure: 0.1 to 0.3 Pa



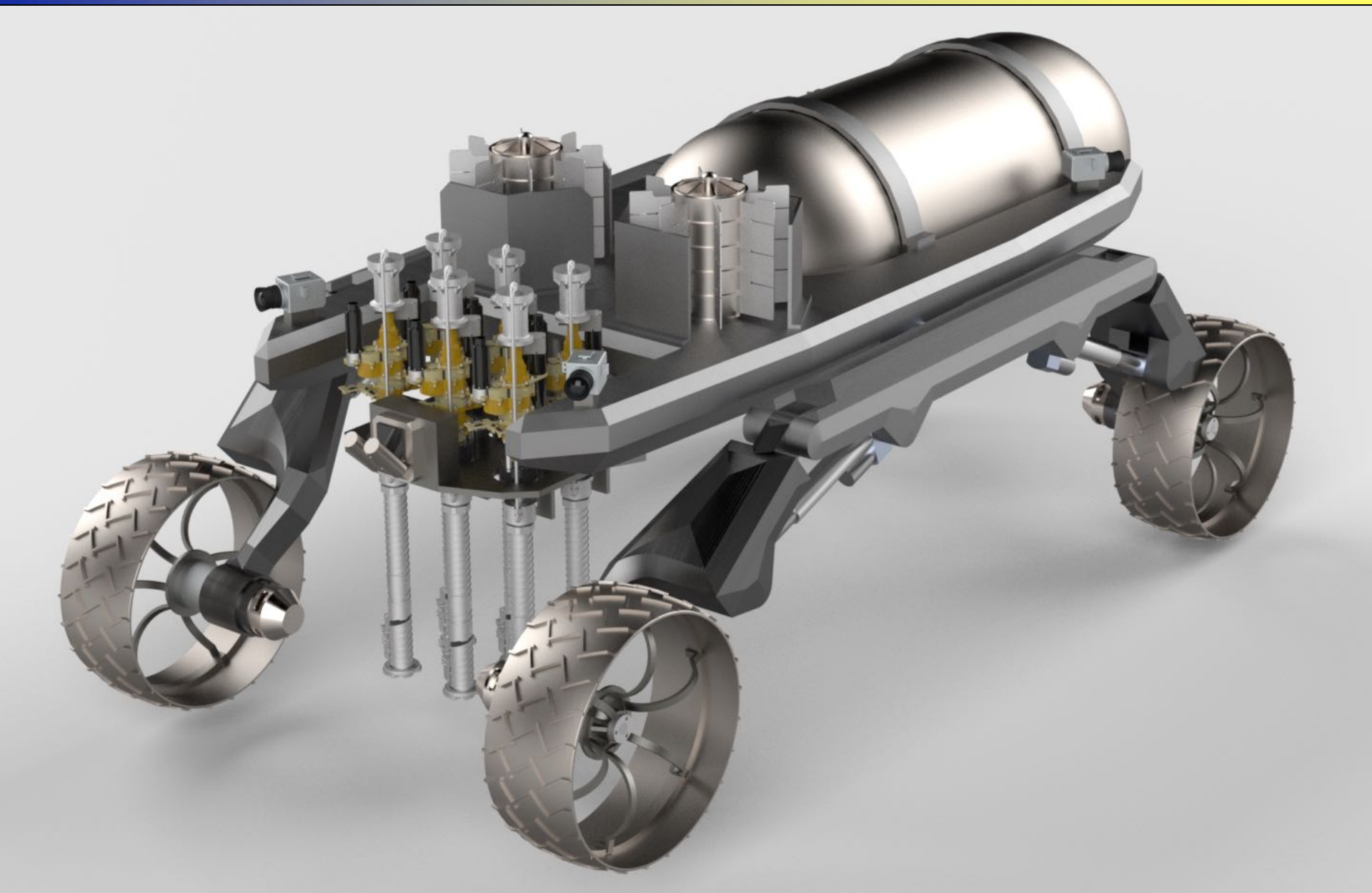
Summary of End-to-End Tests

- NU-LHT-2M
- 1.6 g/cc
- -20C
- 1.5 g/cc
- Chamber pressure: 6 torr

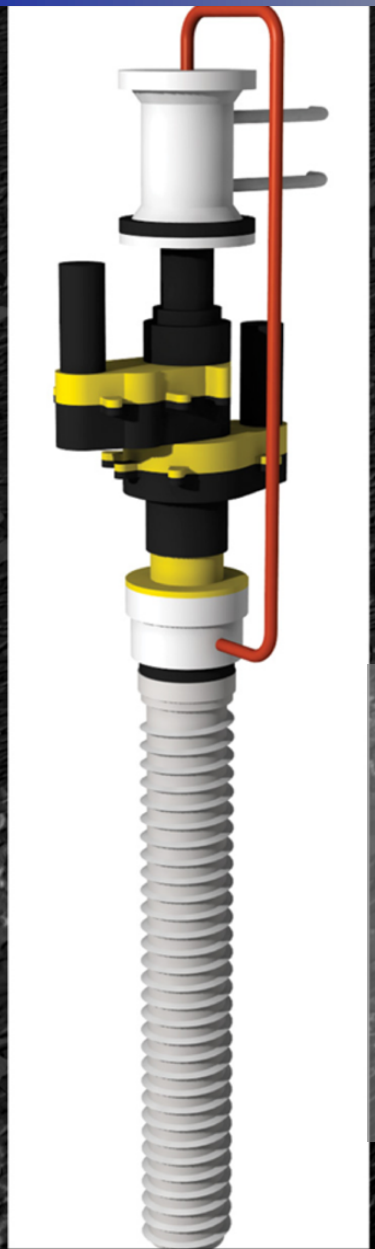


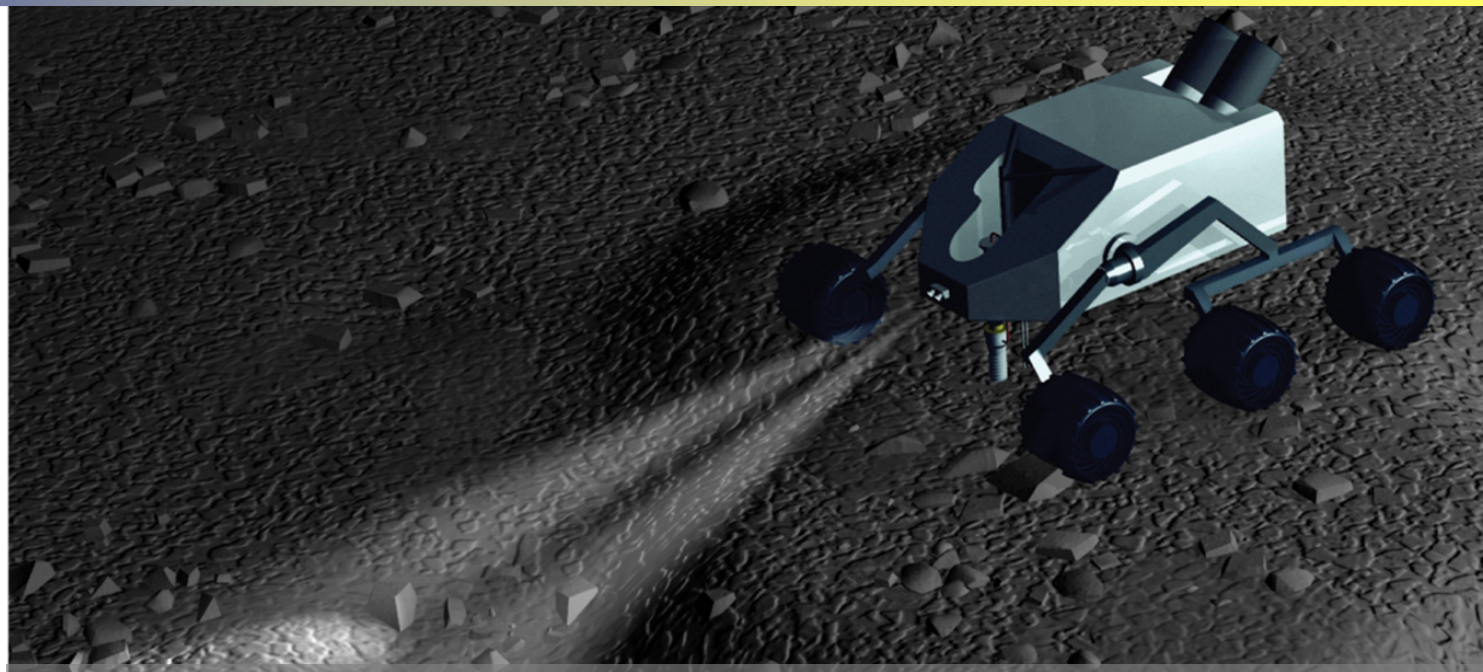
Water Sat	Drilling		Water Extraction				
Wt%	ROP	Power (Elec.)	Water extracted		Heating		
%	mm/s	W	g	%	W	min	Eff (%)
5	1.24	89	4.0	6.8	100	90	4.0
5	0.98	-	5.1	7.4	100	120	3.8
6	0.86	108	30	43	50	720	7.5
4	1.76	84	15.4	56	100	90	15
5	1.74	70	15.1	44	120	60	19

PVEx Miner



Conclusions





- **PVEx can be used for:**
  - Prospecting (delivery of volatiles to MS)
  - Mining (ISRU)
- **PVEx demonstrated drilling and volatiles delivery**

Illustration: John MacNeill

Thank you!

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